REPORT

ON A

FUTURE WATER SUPPLY

FOR THE

CITY OF WINNIPEG,

MANITOBA,

—BY—

RUDOLPH HERING,

New York, September, 1897.

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The Fire, Water and Light Committee of Winnipeg, Man.

BY E. CHAFFEY, ESQ., Chairman.

GENTLEMEN:

Complying with your request and in accordance with a resolution, passed by the City Council on February 22nd, 1897, that I make an examination and report on certain questions submitted, concerning the water supply and waterworks for the City of Winnipeg, I now beg leave to present the results of my investigation.

I.

INTRODUCTORY.

The questions submitted were:

(1) What is the best source of supply, taking into consideration the quantity and quality of the water?

(2) What are the best means of pumping, filtering, softening and distributing the water?

(3) What portion of the present system, if any, can be used to advantage in connection with the recommended system?

(4) A revision and approval of plans.

(5) Subsequently another question was added by the Chairman, namely: What method of proportioning the payment for such works, is, in your opinion, most equitable and proper?

On my arrival in the City of Winnipeg on March 23rd, I met the members of your Committee, His Worship the Mayor and Col. H. N. Ruttan, City Engineer. Detailed information was then furnished me regarding the present status of the waterworks problem

and also the results of the previous investigations and reports that had been made on the subject. Mr. Isaac Campbell, City Solicitor, furnished me with some of the legal facts in the case, and from Messrs. Nanton and Bissett, representing the Winnipeg Waterworks, I received data concerning those works as they now exist. During that visit the plant was inspected and a general examination made of the territory of the City with reference to the subject under discussion.

By the courtesy of Mr. Wm. Whyte, General Superintendent of the Canadian Pacific Railway Company, it was made practicable to undertake a pumping test to show the yield of a large artesian well, situated on the Company's grounds, and also the effect of such pumping on the other wells in the neighborhood. (Appendix I).

This test indicated that an artesian well supply for the city might be feasible, and Dr. W. A. B. Hutton, professor of chemistry at the Manitoba Medical College, was requested to examine by well-known methods into the chemical features of softening such water, and also other waters that would be considered available for the City's supply. Samples for analysis and softening were selected from artesian wells in the western part of the City, and from the Poplar Springs lying about 17½ miles north of City Hall. The water of the Assiniboine River, the present source of supply, had previously been analyzed and reported upon, and it was therefore not further examined. (Appendix II).

Besides these investigations, a number of maps, profiles and topographical data were prepared and compiled at my request, prior to the second visit to your City, which was made in July.

The pumping experiments at the Canadian Pacific Railway well, conducted during the last days of March, had meanwhile been worked up. Profiles of the water levels in many private and public wells of the neighborhood had been plotted, and from these Plate I was compiled. One profile shows the levels on Sunday, March 28th, after pumping had been stopped for a day, another represents the levels at ordinary times, and was taken on March 27th ; and a third shows the levels when the pump was throwing water at a maximum practicable rate.

Plate I. shows two sections, one along the line of the Canadian Pacific Railroad and another at right angles to it, both passing through the test well.

The latter section shows approximately how far in a lateral direction the draft from this one well extended during the time of maximum pumping, namely, from south of Pacific Avenue to north

of Dufferin Avenue, in all a distance of about 4000 feet. The other section shows that the effect of this pumping was lost at the Dog Pound, was slight at the Fair Grounds and was quite material easterly of the tested well.

From these results, and from the further statement made to me, that at low water in the Red River there are innumerable small springs emptying into its bed, we may conclude:

(1) That the artesian wells in the City generally draw from the same underground source.

(2) That this draft, when the water had been lowered to a depth of +11 feet above city datum, extended to a distance of about 2000 feet in a southerly and about 2000 feet in a northerly direction. The draft was noticed, however, at a much greater distance in a westerly direction, and at a still greater distance in an easterly direction, indicating a western source for the artesian water.

(3) That there is a downward slope of the natural water level of these wells in an easterly direction, both when pumping had ceased for a day and when it had been continued for a day at the maximum rate of flow.

(4) That this maximum rate of flow at the Canadian Pacific Railway well after a day's continuous pumping was at the rate of about 150,000 gallons per 24 hours, or about ¼ of a cubic foot per second.

(5) That, in view of these observations, and further justified by the geological formation of the near country, there is a continuous flow of water from the west, through crevices and fissures in the limestone rock, into the Red River.

(6) The continuous flow increases with the depth to which the water is pumped, because this can then be drawn from a correspondingly greater distance and therefore from a larger territory. At a depth of +4 feet [illegible] feet below the surface of the ground in the western part of the City, it is, in my opinion, reasonable to expect an average daily flow of at least 40 cubic feet per lineal foot on a line running about north and south and extending north of the City.

Dr. Hutton's report, dated July 17th (Appendix III), indicates the quantity of lime and soda with which the water of the City wells and that of the Poplar Springs could be rendered satisfactory for domestic and boiler purposes.

On August 9th, in the presence of Mr. Chaffey, Col. Ruttan and myself, Dr. Hutton experimented on the softening of the

water obtained from the Ross Avenue wells, using the amounts of lime and soda stated in his report. The demonstration was satisfactory, as the water was not only softened but found to have been improved also in taste.

In view of the favorable report on the natural character and hardness of the Poplar Springs water, a visit was made to the springs on July 27th. The water was then found to be excellent in taste and appearance, and another sample was taken and sent to Dr. Edgar B. Kenrick, Professor of Chemistry in the University of Manitoba, for analysis. (Appendix II.) An approximate gauging was made by float measurements which indicated a flow of 5.3 cubic feet per second, or at the rate of 2,854,000 gallons per day.

There are other springs in the neighborhood, and it was said that borings have always yielded water wherever wells were sunk on the territory between the springs and Stony Mountain, the water flowing out on the surface in every case.

Stony Mountain is formed of limestone rock, similar to that underlying Winnipeg and cropping out at the City quarries. There can hardly be a doubt that the entire territory between the mountain and the City is underlaid by the same limestone formation, and therefore would yield water by boring into it.

This rock is slightly soluble in water and the solution makes the water hard after it has long been in contact with the rock. The gradual dissolving of the limestone by the flowing water has caused the originally minute fissures to enlarge and multiply in number between the points where the rock has been penetrated by the rain, river or lake waters and the Red River, where it now finds outlets and freely flows off.

Any deficiency in the water found in the Poplar Springs could therefore be made up by wells bored along the line of the conduit, either near the Springs or between them and the City. (A profile of this conduit is shown on Plate II.)

A report was made to the City Council in February, 1895, by Mr. Walter Moberly, C.E., advocating the Winnipeg River as the best source of supply for the City.

His grounds for urging this source, which had also been urged by others, are apparently that the supply is plentiful and the water soft. No engineering data existed by which the merits of this plan for supplying the City could be definitely ascertained, and therefore it was determined to have a survey made of the best line along which a conduit could be built, also to make a personal

visit to the river and to have the water analyzed. It was a favorable time for a visit and for making an analysis, because the water was probably at its least good condition, owing to the large amount of vegetable matter found in such rivers during the latter part of the summer.

Colonel Ruttan, City Engineer, accompanied me on this inspection made July 31st. The profile of the route (Plate II) and the chemical analyses of the water (Appendix II) are attached to this report.

The present source of the City's public water supply is the Assiniboine River, and it is also available for supplying the city in the future. No inspection of this river was made by me, other than within the city limits, as several reports* had already been made thereon, and as little else could be gained from further investigation.

In case this source might be found preferable to the others that have been proposed, it would be desirable to retain as much of the present waterworks plant as could be used to advantage in connection with new works. Another examination was therefore made of the pump house on August 5th, and an interview had with Mr. Bissett on August 7th. A brief description follows:

The works are owned by The Winnipeg Waterworks Company, E. H. Bissett, Esq., Manager. The charter was granted December 23rd, 1880, but they were not put in operation until 1882. The franchise is exclusive, and was awarded for a term of twenty years, therefore terminating December 23rd, 1900.

The source of supply is the Assiniboine River. The intake and pumping station are located at Armstrong's Point on the north bank of the river just below Maryland street bridge, and near the lower end of Mulligan Avenue.

The station consists of an old and a new plant adjoining each other and surrounded by ornamental grounds. The buildings and grounds are in good condition.

A brick conduit or tunnel, 30 inches in diameter, draws the water for the old plant from the edge of the low-water channel and discharges it into a pump-well under the engine room erected near the bank of the river. Its present condition was not ascertained.

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* FOOTNOTE: Report on the Assiniboine River and Artesian Wells as sources of supply By H N. Ruttan, City Engineer, October 20th, 1896.

The machinery was built by R. Laidlaw & Son, Glasgow, and consists of two vertical pumps, double acting and driven by cranks from a shaft. The shaft is turned by gearing, driven by two engines quartering on the same. The engines are double, horizontal, high-pressure and condensing, but not compounding. The nominal horse-power is said to be 60, and the original capacity was rated at 1,500,000 gallons per day. Their present condition is not first-class.

At the present time the Laidlaw pumps are used only to supplement the new pumps during the hours of greatest consumption, and, as I was informed, to the extent of between 85,000 and 165,000 gallons during 6 or 7 hours in the day, for a part of the summer. Adjoining is the boiler room, but the old boilers are out of use and abandoned.

The new pumping station was completed in 1894, and a new brick conduit five feet in diameter was built and extends nearly to the centre of the river. The conduit encloses a 24 inch cast iron suction pipe, and two small pipes, one to supply a donkey pump and the other to carry the overflow from the hot well and to prevent ice from forming at the intake. Its present condition was not ascertained, but was stated to be good.

The pumping machinery was built by Arthur J. Loretz & Co., of Allentown, Pa., and was finished in 1894.

The pumping engine is of the walking beam type, high duty and compound. One end of the beam is connected with the piston-rod of the two cylinders, while the other is connected with a fly-wheel. The pumps are operated from the beam at half distances, one on each side. The maximum capacity was stated as being 2,500,000 gallons. The engine was making 26 revolutions per minute when examined by me at the hours of maximum draft. It was stated that it had been run up to 33 revolutions.

The present condition of these engines does not appear to be first-class. With proper care they can, however, be made serviceable until beyond the time when the franchise expires.

The new boiler house contains three boilers, built by the Waterous Engine Works Co., Ltd., of Brantford, Ont. Each one is 4 feet in diameter and 14 feet long and is said to furnish 45 horse-power. They carry 95 to 105 lbs. pressure, and appear to be in a good condition.

From statements made to me I find that the new pumps are used at the present time to supply a daily quantity of water of about 1,250,000 gallons in summer and about 850,000 gallons in winter.

Adjoining the new engine room is the filter house, containing five filters made by the National Water Purifying Company of New York, three of which were erected in 1887, and the other two in 1889. They operate under the full pressure of the pumps and therefore are, what is termed, pressure filters. They are said to consume from 5 to 15 lbs. of pressure, depending upon the character of the water. The casings are 10 feet in diameter and 7 feet deep. They are washed once daily in winter, at the present time twice daily, and in spring when the water is very muddy it is necessary to wash them as often as once every two hours. They are apparently in good condition.

It is stated, that formerly during the spring ½ grain of alum per gallon was added to the supply, to aid in coagulating the organic matter, and thus assist the clarification. But for two years the practice has been discontinued, and it could not be done without materially reducing the pressure in the City.

From the fact that the number of filters is insufficient for the quantity of water that must pass through them, when it contains much suspended matter, also from the fact that therefore no alum is used and that they are pressure and not gravity filters, they do not always deliver clear water. They can often but partially remove the turbidity, and when the river is very muddy they clog up so quickly as to be rendered entirely useless at such times.

No attempt is made to soften the water.

It is estimated that the quantity of water supplied to the City by all the pumps at the station now ranges from 850,000 to 1,415,000 gallons per day, the yearly average being given as 1,000,000 gallons.

The distribution system of pipes supplies only a part of the City, namely: The tract lying between Kennedy and Main Streets from Portage Avenue to the Assiniboine River; the tract south of Main Street, between Notre Dame and Common Streets; and the tract north of Main Street bounded by Notre Dame, Ellen, Jemima, Isabel, McWilliam, Machray and Logan Streets.

From the pumping station a twelve inch main extends along Mulligan Avenue to Broadway and thence a ten inch main to Portage Avenue and down the latter to Kennedy Street. From Mulligan Avenue an eight inch main extends down Broadway to Main Street and along the latter to the C.P.R. station. From these mains six inch, five inch and four inch branch lines extend in different directions.

When the works were inaugurated the pipes laid in the ground were cast-iron, apparently of good quality, but cast horizontally, and therefore they have uneven thickness. As they have turned and bored joints, no lead being used, they are also apt to allow of leakage under high pressures. There are between four and six miles of such pipe still in use, according to different statements made to me. Since 1887 nothing but cast-iron pipes have been used, having bell and socket joints caulked with lead. It is said that some lead jointed pipe was laid previous to that year. They are believed to be in good condition.

The service pipes that were first laid were of wrought or galvanized iron. They were not found to be durable, as has also been found elsewhere. They are apt to corrode rapidly and then will not deliver sufficient water nor stand much pressure. The newer service pipes are of lead and should therefore be satisfactory.

There are somewhere between 1500 and 1600 taps now supplied with water by the Company. Exact figures were not given.

During the last fiscal year the City consumed for public purposes about 12,400,000 gallons of water supplied by the Company, or about 34,000 gallons per day. There are four drinking fountains which together flow about 5,000 gallons per day. Elevators consume about 10,000 gallons. For filter washing purposes at the works there are used about 30,000 gallons and for condensing purposes about 13,000 gallons. In all there are 92,000 gallons consumed on the average per day for other than domestic purposes, leaving for the latter but 908,000 gallons per day.

Assuming that there are 1500 taps in use, we have 605 gallons daily per tap. If we reckon six persons per tap, then 9,000 persons are furnished with water by the Company. For public purposes, including elevators, 49,000 gallons are daily furnished. If we assume that 36,000 persons are at present benefitted by this quantity, then 9,000 would have the benefit of one-fourth of the quantity, or about 12,000 gallons, which, added to the above amount, gives 920,000 gallons as the domestic and *pro rata* public consumption for 9,000 persons, or 102 gallons per head per day. If we reckon 7 persons per tap, a population of 10,500 would be supplied, or 88 gallons per head per day.

This amount represents a large consumption per person, and may be due, as I am informed, partly to leaky pipes and hydrants, and partly to the wastefulness of the users, who are said often to allow the water in the house to run freely and continuously, in order to prevent their pipes from freezing in winter and for lawn sprinkling in summer.

With the idea of indicating the large amount of water which can be wasted by leaky faucets, a gauging was made of one which was observed by me to leak, in March and also in July, and is said to have been in this condition between these dates. The washer was probably worn out and the faucet could not be shut tightly. The small dribble amounted to 75 gallons per day. When informed that there were hundreds of faucets in the City which were in the same condition; when considering the disposition of careless persons not to turn the water off immediately after use; when noticing many leaks at public hydrants; and being informed that an inspection last February showed 99 to be leaking, from indications on the surface of the street and in the sewers, it is not surprising to me that the consumption per capita is so high.

It should be added that, as the Assiniboine water furnished by the Company is hard, many persons do not use it for laundry purposes, but instead use rain-water collected in cisterns, or use melted ice.

The objectionable features of the present supply, which it is sought to remedy, are:

1. The distribution system does not extend over all parts of the City needing water.

2. There is insufficient fire pressure in most parts of the City which are supplied with mains.

3. There is an insufficient number of efficient fire hydrants, and therefore also a lack of water immediately available for large fires.

4. The water as furnished in spring, summer and autumn is at times liable to be quite turbid, and has once also had a very disagreeable taste, due to foul organic matter that was washed into the river and which the filters could not remove. There is no reason why this condition should not occur again.

5. There is a suspicion of organic pollution, indicated by the analysis (Appendix II.) and due probably to settlements along the shores, to the habit of dumping manure and other refuse into the stream, and possibly also to the city dump for garbage and excreta, which lies near a water course discharging its water above the Waterworks intake.

In order to examine into the relative merits of the different sources of supply which have now been mentioned, and to calculate the right proportions for the distributing system, and also to estimate the cost of the works, it is necessary to establish the quantity of water which is to be daily furnished the City for domestic and

public purposes, and also the water pressures which are to be maintained in the pipes at ordinary times and during the occurrence of fires.

In his report of May 6th, 1895, Colonel Ruttan states that the new supply should provide at once for 40,000 people and later be capable of supplying 100,000 persons. Fire protection is to be secured by 10 contiguous hose streams, each of which discharges 35 cubic feet per minute, at a pressure of 75 pounds per square inch at the hydrants in the business centre. This is a larger supply for fire protection, he says, than has been usual, but adds that it is warranted by the local conditions.

We must realize that a good water supply for Winnipeg will not be inexpensive. All of the water must be pumped and perhaps purified and softened. The territory to be supplied is large compared with the population to be served. Therefore, the quantity should be kept down as low as possible.

As already stated, the daily consumption per head is probably between 88 and 102 gallons, which is quite large, and there appears to be much leakage and unnecessary waste. It is reasonable to suppose that the requisite quantity of water can be materially reduced and kept within proper limits by preventing such leakage in the public mains and hydrants and by placing meters for private consumers. At the present time, both in Europe and the United States, this waste is greatly reduced by metering the water for private consumption, in the same way that gas is metred.

It has been said, in objection thereto, that among certain classes metering would prevent the use of a sufficient quantity of water for keeping clean and other sanitary purposes; but this criticism would be rendered invalid by the practice of charging each consumer a certain fixed minimum rate for an allowance of water considered reasonable and ample. Whatever quantity is consumed in addition thereto is paid for at fair meter rates.

This method not only guards against a disposition to stint in the use of water, but at the same time it makes every water user pay more nearly in proportion to what he consumes. Incidentally, the consumer himself will be interested in preventing undue waste and leakage from the faucets in his house, and therefore will assist the City in maintaining a fair supply and in reducing the expenses of pumping and softening.

To reduce the consumption it will also be wise, while furnishing a high pressure in the mains during a fire, to maintain only a moderate pressure during ordinary times and a still lower one at

night. Both the legitimate use of water, as well as the waste, dispose of larger quantities under high pressures than under low pressures.

As you are about to change or re-arrange your water supply, it will therefore be a favorable time to introduce meters. Such introduction can be very strongly recommended to you.

The following table gives the consumption and pressure in several cities having conditions which allow comparison in one way or another with those in Winnipeg:

CITY.	Population Supplied.	Average Consumption.		Pressure, lbs. per sq. in.	
		Daily in millions of Imp. Galls.	Per Head in Imp. Gallons.	Ordinary	Fire.
London, England	5,030,000	115.2	31.5		
St. Petersburg, Russia.	960,000	32.3	33.3		
Hamburg, Germany ..	583,000	26.5	44.0		
Dublin, Ireland	327,000	14.9	46.2		
Providence, R. I.......	132,146	7.4	56	39	73 to 86
Fall River, Mass	74,398	2.6	35	80	80
Atlanta, Ga..........	65,533	3.8	58	60	80
Dayton, O.	61,220	3.2	52	60	100
Lynn, Mass..........	55,727	3.6	65	50	65
Lincoln, Neb.........	55,154	2.5	45	30	100
Lawrence, Mass	44,654	2.5	56	65	65
Sioux City, Ia.......	37,806	1.1	29	110	140
Fort Wayne, Ind......	35,393	2.5	71	45	45
Quincy, Ill..........	31,494	1.0	31	30	90

Col. Ruttan holds the opinion that by the use of meters the present consumption can be reduced to an average of 60 gallons per head per day. I fully agree with him in this opinion, provided the works are well designed and well managed, if the present leaks are avoided and meters are introduced on all service pipes and a moderately low pressure of from 30 to 40 pounds per square inch is kept on at ordinary times during the day, and a still lower one, say, 20 to 25 pounds at night, while a high pressure of 75 pounds per square inch is maintained only during fires.

I also agree with him that, at the present time, it is not necessary to calculate on more than 40,000 persons taking water

from the City's supply. At 60 gallons per head this gives an average daily supply of 2,400,000 gallons. The maximum rate of consumption during the day should be placed at 75 per cent above this average, which gives a rate of 4,200,000 gallons for which the City mains and pumping machinery should provide at the outset, together with arrangements for future extensions, as may be found necessary.

Provision should at once be made in such parts of the work which cannot easily be extended or enlarged, for a population of 100,000 persons.

There is an irregular draft of water during the day, liable at times to be nearly double the average daily draft, and as the supply will be delivered at a uniform rate, whether it comes from a distant source through a conduit, or from softening works and filters in the City, it is in every case necessary, therefore, to have a reservoir in which the regular flow of water can be received and stored, to be drawn by the City pumps and forced into the mains in such quantities as may be required at any moment. Such a distributing reservoir should have a capacity of at least one million gallons when the works are started. When the population to be served reaches 100,000 the total reservoir capacity should be at least between 2,000,000 and 3,000,000 gallons.

The high degree of hardness of the natural waters near Winnipeg, and the desire to have a soft water for the City's use, make it advisable to state here in a general way why the water is hard, and how it can be softened.

Water is hard, generally, when it contains in solution bicarbonates or sulphates of lime or magnesia, or both. The hardness is commonly recognized by the fact that when soap is added in the usual quantity for washing, a curdling is produced instead of a lather. Hard water is objectionable mainly on this account and also because the precipitation of lime or magnesia in boiling water causes the formation of scale in boilers.

The advantages of soft over hard water for a community may be stated briefly as follows:

Hot water is obtained more quickly and less fuel is required. The saving of soap and soda in the household is considerable. The labor of washing is much reduced. The wear and tear of clothing is diminished. Flannels last longer and do not become harsh and felted. Cooking is facilitated. The same quantity of tea that will make three cups with hard water will make five cups with soft water. (Evidence before Royal Commission). The palata-

bility is often increased. The softening process does not make water insipid like distilled or rain water.

There are two kinds of hardness: Temporary and permanent. The former is usually caused by the carbonates and the latter by the sulphates of lime or magnesia.

Temporary hardness can be removed:

1st. By a sufficient quantity of soap.

2nd. By carbonate of soda (washing soda). The carbonate of soda unites with the bicarbonate of lime dissolved in the water, resulting in the formation of bicarbonate of soda and carbonate of lime. The former remains in solution and does not harden the water, the latter is precipitated as a fine, white powder.

3rd. By boiling. The bicarbonate of lime is decomposed by heat into carbonic acid, which escapes, and carbonate of lime, which is precipitated as a fine white powder.

4th. By a solution of freshly burnt lime, or lime-water. The carbonates of lime and magnesia are changed into mono-carbonates by the hydrate of lime uniting with the extra carbonic acid, which is either free or combined as bicarbonate in the hard water. The resulting insoluble mono-carbonates deposit as a fine powder. Carbonate of lime is not entirely insoluble in water, and a small portion always remains in it. The soluble bicarbonates of lime or magnesia, having thus lost half their carbonic acid, are reduced to the same insoluble mono-carbonates and are also precipitated. This process, being the least expensive, is the one here recommended.

Permanent hardness can be removed:

1. By a sufficient quantity of soap, as before.

2. By carbonate of soda. The soda in this case unites with the sulphate of lime or magnesia dissolved in the water, resulting in the formation of the neutral and inert sulphate of soda, and the insoluble carbonate of lime or magnesia. The former remains in solution and does not harden the water, the latter is precipitated as a fine, white powder. In cool water the presence of free carbonic acid, or of bicarbonates, interferes somewhat with this reaction; but the combined lime-and-soda process obviates this difficulty to a large extent. As permanent hardness is usually present with temporary hardness, the lime and soda can be mixed and together added to the water.

To remove permanent hardness this process is the least expensive one for city supplies.

The soda should be dissolved and the solution thoroughly mixed with the water to be softened. The lime should be freshly burnt and added, not as milk-of-lime, but as lime-water. Accurate proportions can be more readily obtained with the latter than with the former. The precipitate settles slowly and in practice it is found best to strain it out of the water by filters. The solid carbonates are then either allowed to settle and dry, and are removed by excavation, or they are at once passed through filter presses. The water draining from the precipitate often contains sufficient lime in solution to be used over again.

If the work of softening is properly done there is no free lime left in the softened water. The softening with lime will incidentally also remove a certain quantity of iron contained in the water. It has also the effect of removing some organic matter.

Cloths may not filter efficiently until a thin layer of deposit has coated them, which tends to fill up or reduce the sizes of the interstices in the web. If the precipitate is of a glutinous nature, or caused by hydrate of magnesia, which is not crystalline, or by organic matter, the speed is rapidly lessened, and the cloths soon stop up and therefore require more frequent washing. In such a case settling basins should be used to accomplish the heavy part of the work before the water is passed through the filters.

Soda is somewhat destructive to cloth. When there is much of it contained in the water, cloth filters may not be economical.

After considering this preliminary information, the questions submitted to me by your Chairman were carefully considered in the light of the facts before me.

In answer thereto the following conclusions have presented themselves:

II.

SOURCES OF SUPPLY, PURIFYING AND SOFTENING THE WATER AND DELIVERING IT TO THE CITY.

A.—Assiniboine River.

The Assiniboine River is a branch of the Red River and discharges into the latter at Winnipeg. Its drainage area is about 58,000 square miles and is almost all prairie land.

The annual rainfall upon the area is estimated at 18 inches per annum. The maximum flow is given as 1.0283, the minimum flow as .016, and the ordinary flow as .044 cubic feet per second per square mile of drainage area.

High water occurs in April and May, and low water in the early winter, from which time until spring the river is covered with ice and remains at about the same level.

The above flow per square mile is very small, which is due partly to the small rainfall and partly to the great evaporation which takes place from so flat a watershed, on account of the low average degree of humidity prevailing in that part of the country.

It has been intimated that Lake Manitoba may partly drain into the Assiniboine River, but this can hardly be so, because its flow is much smaller per square mile of drainage than that of most other streams, the flow of which is known.

The river has but a slight fall and many sinuosities.

Regarding the quality of the water it may be well to quote the remarks made by James Patterson, M.D., Chairman of the Board of Health, and H. N. Ruttan, Esq., City Engineer, in their joint report on the condition of the Assiniboine River, dated September 30th, 1896.

"On the settled portions of the river, on account of the higher "land of the banks affording drier building sites, the woods affording shelter, and the convenience to water in the river for stock in "winter, all the dwellings, barns and stock yards are placed upon "the immediate banks, and it is the almost universal practice of the "residents to use the river as a dumping place for all kinds of refuse "and offal. Manure is got rid of by throwing it into the river. "Surface washings from barnyards, stockyards and hogpens during "every rainfall find their way into it directly by natural ravines or "artificial ditches, whilst the soakage from all is continually going "on. In fact the river is used as the common sewer of the country.

"The number of persons per square mile in the Assiniboine "watershed probably does not exceed ½ person per square mile at "the present time, a number so small that under ordinary circum- "stances they would have no appreciable influence in the sewage "contamination of the stream, but of more importance on account "of the long narrow shape of the river lots; the location of their "dwellings, out-buildings and yards; the large proportion of stock "kept by each, and the common mode of disposing of manure "instead of using it as a fertilizer. While, therefore, there is no "ground for present alarm from this cause; the indications are that "in the not distant future, as settlement increases, most stringent "measures will have to be enforced to prevent a continually in- "creasing pollution of this stream. * * *

"Between Portage la Prairie and Winnipeg the river banks "are sedimentary and at all stages of water, except the lowest, are "subject to constant and very great erosion, so that for six months "in the year the water carries in suspension great quantities of "finely divided clay and sand. * * * *

"It is considered that this large quantity of sediment carried "by the water is at the present time its most objectionable feature.'

My own examinations, so far as they could be made, would tend to endorse these views:

The chemical analyses of the Assiniboine River water are appended. (Appendix II).

The solid matter contained in the water of the river is high and the hardness is also high, as the river passes through a limestone country. The high percentage of albuminoid ammonia is due mainly to vegetable pollution, such as leaves, stems and roots. Vegetable matter is comparatively unchangeable and does not decompose as rapidly as animal matter, which fact is shown by the small percentage of free ammonia contained in the water.

The attempts made, up to the present time, to purify the Assiniboine River water, have only been partly successful. The filters, as already mentioned, do not operate satisfactorily, and sometimes are entirely useless.

In order to render the Assiniboine River water satisfactory as a public water supply it should be purified and softened.

Purification can only be obtained by the use of settling basins and filters. Filters alone will not be successful. This is due, partly to the irregular character of the water, being sometimes quite clear, and at other times very muddy and carrying in suspension much fibrous organic matter. For the same reason it has not been found satisfactory to clarify the Missouri and lower Mississippi waters by passing them through filters alone.

Settling basins, arranged so as to allow the suspended matter, in its greater part, to subside, are a necessary preliminary to obtaining clear water. The water must subsequently be filtered so that not only the slight turbidity which will remain is removed, but also the organic matter and the objectionable bacteria.

It is not necessary in this case to adopt slow sand filters, such as are used for most of the European water supplies, as the water has not a sufficiently high bacterial pollution to favor such a process. Rapid mechanical filters will answer the purpose and render the water, after it leaves the settling basin, entirely clear, and there need be no difficulty in their operation. These mechanical filters should operate under a slight head securing a constant flow, rather than under high pressure and a varying flow, as at present.

The water of the Assiniboine River can be softened, so as to make it serviceable for washing purposes, by the addition of a solution of lime and soda. These materials could be added while the water is being pumped into the settling basin. Here the carbonates removing the hardness are precipitated, together with the bulk of the suspended river silt and organic matter. The water is thus partially clarified. Subsequently it is passed through filters to be thoroughly clarified, as mentioned above.

It is estimated that for the purpose of clarifying a daily supply of 2,400,000 gallons the settling basins should have a capacity for at least half this amount, i.e., 1,200,000 gallons, or 192,000 cubic feet. It would be well to have a division into at least four basins giving each one a capacity of 48,000 cubic feet.

Allowing the water to stand 15 feet deep, each basin would have an area of 3,200 square feet. They should be covered so as

to be protected from the influence of frost. These assumptions might require modification when the reservoir is located.

After passing the settling basins the water would be lifted into mechanical gravity filters at the rate of 300 cubic feet per day per square foot of filter surface, thus requiring 1280 square feet of area. In order to obtain the greatest efficiency the rate of flow through the filters should be uniform. I have estimated for 7 filters, each having 16½ feet effective diameter. The head required is assumed at 18 feet. One of the filters would be continually out of service for cleaning.

From these filters the water would flow into the reservoir and thence be pumped into the distributing system.

The water used for washing the filters and settling basins, as well as the sediment from the latter, would be carried back into the river.

To avoid the necessity for large settling basins it has recently been proposed to use filters having specially constructed settling compartments. Such filters are now in use in Elmira, N.Y., Lorain, Ohio, and Kansas City, Mo. Whether or not they ultimately answer the purpose of clarifying and purifying the Assiniboine River water, I am unable to state, as experience with such filters is as yet too limited.

Assuming the use of large settling basins, the cost of the plant is estimated as follows:

Land for pumping stations, settling basins, filtering plant, etc.	$ 4,000
Preparing grounds	2,000
Buildings, chimney and foundation for machinery	20,000
New intake	5,050
Pumping machinery, with boiler plant for power and heating, two vertical triple expansion pumps and two horizontal simple duplex pumps	31,800
Mixing plant for chemicals	3,000
Covered basins for settling and softening	40,000
Mechanical filter plant	35,000
Drains for waste water	1,000
	141,850
Contingencies and engineering, 15%	21,280
	$163,130

Assuming the use of filters with small settling compartments attached, this figure would be reduced by the cost of two pumps and the large settling basins, and increased by the cost of a greater number of filters of larger size. The cost of this plant would be about $123,000.

The chemicals required for softening the daily quantity of water (2,400,000 gallons) and for precipitating the suspended matter, are estimated as follows:

Lime..........6720 lbs. at ¼ cent....	$16 80	
Soda Carbonate, 960 lbs. at 1 cent....	9 60	
Alum..........600 lbs. at 2 cents....	12 00	
		$38 40
The daily cost of operating the softening plant and mechanical filters, removing the sediment and organic impurities from the settling basin, and repairs, is estimated at $10.00 per million gallons, or..............................		24 00
Pumping 2,400,000 gallons into the Distribution Reservoir		19 60
Daily operation of softening, filtering and delivering into Reservoir..............................		$82 00

Therefore, the annual expense for purifying and softening the Assiniboine River water to the extent of 2,400,000 gallons per day, and of delivering it into the Distribution Reservoir, would be:

Interest on cost of plant, at 4 per cent	$6,525
Repairs and renewals of buildings and machinery;	2,000
Operation of softening, purifying and pumping, at $82.00 per day..............................	30,075
	$38,600

If filters with settling compartments are used, the cost of the daily operation might be reduced from $82 to $75, making the total annual cost:

Interest on cost of plant, at 4 per cent......	$4,920
Repairs	1,900
Operation, at $75 per day..............................	27,375
	$34,195

To ascertain the net expense of softening the water, as against supplying it unsoftened, but passed through settling basins and

filters, I append an estimate for supplying purified but hard Assiniboine River water.

There would be a reduction of $3,560 in the cost of the chemical softening plant and buildings, making the total cost of the work $159,570, when using large settling basins, and about $119,440, when using filters with settling compartments.

The average daily cost of settling and filtering is estimated at $14. The cost of pumping, if at the same station where the water is pumped into the distribution system, would be $16 per day. The whole operation would cost $30 per day, or $10,950 per annum.

Therefore, the annual expense of merely purifying, but not softening the Assiniboine River water and of delivering it into the distribution reservoir would be:

Interest on cost of plant, at 4 per cent	$6,383
Repairs and renewals of buildings and machinery	1,800
Operation of purifying and pumping at $30 per day	10,950
	$19,133

If filters with settling compartments are used, the daily cost of operation might possibly be reduced to $26, making the total annual cost:

Interest on cost of plant, at 4 per cent	$ 4,778
Repairs	1,700
Operation, at $26 per day	9,490
	$15,968

From the above figures it is computed that the daily cost of softening 2,400,000 gallons per day will be $53.33, when large settling basins are used, and $49.94 when only settling compartments are attached to the filters. Therefore, the cost of softening 1,000 gallons of Assiniboine water by the former method is 2.22 cents, and by the latter method 2.08 cents.

B.—Artesian Wells.

Borings made in the limestone rock which underlies the City of Winnipeg, yield water, as has already been mentioned. It is clear in appearance and in most cases palatable as a drinking water, but it is very hard. (Appendix II). In some of the wells the iron piping seems to affect the taste slightly, but it is practicable to remove this taste by properly asphalting the pipes, and

also by the process of softening. The excessive quantity of salt which it contains is not sufficient to condemn the water for drinking, or other purposes, as it is not due to organic pollution. The analyses show it to be entirely free from such pollution.

From the overlying strata of impermeable clay it is impossible that any surface water in the City, as for instance from the streets, sewers, privies or cemeteries, would penetrate into the artesian water. This fact is demonstrated in the western part of the City by the water rising above the surface of the ground when a well is piped. Its source must therefore have a higher elevation and consequently be at a distant point from the City.

The analyses of the water from different wells, made at different times, agree fairly well. (Appendix II.)

It is stated that in no case where the boring was made deep enough has such a well failed to furnish water. It is also said that sometimes the water has had an unpleasant taste, but that by sinking the well deeper this taste has disappeared.

From the test made at the Canadian Pacific Railroad well it was demonstrated that a continuous supply of this water can be obtained. It was also demonstrated that the water came from a westerly direction, and that to collect the same, it would be necessary to sink a row of wells along a line having a northerly direction.

It has been remarked that the possible source of the artesian water might be Lake Manitoba. While this is possible it is not at all necessary for our purpose to suppose such a source, as the amount which may be drawn from the wells to supply the City of Winnipeg might be supplied by the rainfall which soaks down into the ground between this City and Lake Manitoba. The impervious clay stratum overlying the limestone rock is found only in the Red River Valley. Beyond it the soil is more porous. The rock crops out at the surface but a few miles west of Winnipeg. Between such outcroppings and Lake Manitoba there is abundant opportunity for that part of the rainfall, which does not evaporate or run off into the streams, to penetrate the ground and enter the fissures of the rock.

In my opinion, there will be no great difficulty in obtaining all the water required for the City from this artesian source. It is only a question as to how far north to extend the pipe line and the wells to get the necessary quantity. For the purpose of making an estimate of cost it has been assumed that such an intercepting pipe line to supply 2,400,000 gallons per day will have to be at least 5,000 feet long.

The water derived from this source, being always clear and without organic pollution, need not be purified. As its hardness is great, being a little greater than that of the Assiniboine River water, it would be desirable to soften it.

No settling basins are necessary, as no preliminary clarification is required. The precipitate which is caused by the softening process must, however, be removed from the water. Instead of using mechanical filters for this purpose, cloth filters will answer better and be less expensive. Such cloth filters have been used for several years in the water-softening plant at Southampton, England, and to clarify the Spring Valley water supply of San Francisco.

It is possible that some use might be found for the material which is strained out by the filters; but it is more probable that at first it will have to be stored upon the ground near the works. From 2,400,000 gallons of water there would be about six cubic yards of precipitate. (Appendix III).

The water used for washing the filters and washing out the precipitate, would have to be removed in a sewer or drain to be provided for the purpose. If the works are located north of the Exhibition Grounds, the drain could discharge into the ditch now running alongside of the Selkirk Branch of the Canadian Pacific Railway, or would have to be built to the Red River.

The cost of this plant is estimated as follows :

Land for pumping station, softening plant and wells	$3,500
Preparing grounds	1,500
50 wells, with connecting pipe, laid in a brick conduit	57,500
Buildings for pumps, boilers, fuel and softening plant	25,000
Chimney and foundations for machinery	3,500
Softening plant and filters	25,000
Two horizontal triple expansion pumps, with boiler plant for power and heating, etc	17,750
Drains for waste water	5,000
Deposit tank for precipitate,	2,000
	$140,750
Contingencies and engineering, 15 per cent,	21,120
	$161,870

The chemicals required for softening the daily quantity of ater (2,400,000 gallons) and for precipitating the suspended matr, are estimated, according to Dr. Hutton's data (Appendix III), sing the average amounts of chemicals given by him, as folws:

Lime..........7800 lbs. at ¼ cent.....	$19 50	
Soda carbonate, 1080 lbs at 1 cent.....	10 80	
Alum.......... 600 lbs. at 2 cents	12 00	
		$42 30
Labor for the softening plant and for repairs....		12 00
Pumping 2,400,000 gallons from the wells into the tanks (maximum lift) at the city distribution pumping station........................		12 00
Daily operation of softening and delivering into reservoir..................................		$66 30

Therefore, the annual expense of softening the artesian well ter, to the extent of 2,400,000 gallons per day, and of delivering nto the distribution reservoir, would be:

Interest on cost of plant, at 4 per cent..........	$6,475
Repairs and renewals of buildings and machinery	1,500
Operation of softening and pumping, at $66.30 per day..................................	24,200
	$32,175

To ascertain the net expense of softening this water, as inst supplying it unsoftened, I append an estimate of cost for pplying it in its natural condition.

There would be a deduction of $54,470, for decrease in the cessary land, size of buildings, pumping and softening machinery, ains, deposit tank, and foundations. The total cost of the work estimated at $107,400.

The average daily cost of pumping, maintenance and delivery to the reservoir at the pumping station, is $12.00, or $4380 per nnum.

Therefore, the annual expense of delivering the natural artesin well water into the distribution reservoir would be:

Interest on cost of plant, at 4%	$4,296
Repairs and renewals	1,000
Pumping, at $12	4,380
	$9,676

From the above figures it is computed that the daily cost of softening 2,400,000 gallons per day will be $61.64. Therefore, the cost of softening 1,000 gallons of artesian well water is 2.57 cents.

C.—Poplar Springs.

These springs are located to the north of the City and 17½ miles therefrom. They have an elevation of 8 feet above the City. The territory between is flat, as shown by the profile attached hereto (Plate II), the greatest rise being 16 feet above the elevation of the City, at 11 miles therefrom.

The quantity of water, as gauged at the large spring in July, is about 2,800,000 gallons per day. It may be less later in the season and in the winter.

As stated above, it is probable that by boring and intercepting, a much larger quantity of water of a similar character could be obtained. It is certain that the quantity first demanded by the City can be secured from the large spring alone, and later, by reaching the other springs, or by intercepting sufficient artesian water between the springs and the City, the future average amount of 6,000,000 gallons per day can be obtained.

The water of the Poplar Springs is very clear, without organic pollution, and need not be purified. Its hardness is not as great as that of the city artesian water, nor as great as the Assiniboine River water, and according to Dr. Kenrick its hardness is only temporary and can be removed with lime alone. (Appendix II.)

While it is by no means a soft water, it might perhaps be considered sufficiently soft for city use. For washing purposes it would be desirable to add some soda to it. This should be done the day before using it, so that the precipitate will settle, the clear water can be poured off for use, and the sediment thrown away.

If subjected to a softening process by the City, the works should be located near the springs. The water would there be lifted into a softening basin, receive the necessary chemicals and be filtered through cloth, as in the case of the artesian well water.

The water used in washing the filters could be led into a ditch near by, which now carries off the water of the springs.

The distance from the City necessitates the laying a conduit to it from the springs. It would be sufficiently large and durable to carry not only the quantity of water at once required, but the future quantity of 6,000,000 gallons per day, or 11.14 cubic feet per second.

Wooden stave pipe, if it is constantly under pressure, is, I believe, as good, in your climate and conditions, as iron pipe. If

under pressure and not painted, the wood remains saturated, the ap is removed and decay postponed, if not entirely prevented. Such pipe will readily stand 100 feet pressure. The steel bands used should be of the best material, of ample strength and carefully made. They should be well coated with properly prepared sphalt.

The total length required is about 92,400 feet, or 17.5 miles. The diameter should be 36 inches. The loss of head in this conduit uc to friction is assumed at 0.329 per thousand, when carrying ,000,000 gallons per day, and 0.064 per thousand when carrying 400,000 gallons per day. In case a stave pipe is used, the friction ight be slightly reduced.

The necessary total lift to deliver the water of the springs to the City's reservoir is 31.5 feet for 6,000,000 gallons daily, d 11 feet for 2,400,000 gallons daily, not considering the special t for the softening process, which is 10 feet additional in each se.

There would probably be several summits in the pipe at which -escape valves would be required. It is estimated that the top the pipe is covered with at least six feet of earth to prevent the ter from freezing. The conduit would discharge into the distution reservoir in the City, from which, as in the other cases, water would be pumped into the City mains.

The cost of plant is estimated as follows:

Land for pumping station, softening plant, springs and pipe line	$ 1,200
Preparing grounds	500
Developing springs, well, etc	3,000
Buildings for pumps, boilers and softening plant	25,000
Chimney and foundation for machinery	3,500
Dwellings for men	2,500
Softening plant and filters	25,000
Two horizontal compound condensing engines and two simple high pressure engines with boiler plant for power and heating	18,250
92,400 feet of 36 in. stave pipe, including valves, etc	388,000
Deposit tank for precipitate	2,000
	468,950
Contingencies and engineering, 15 per cent	70,340
	$539,290

Although requiring a smaller quantity of chemicals, the cost of softening would be nearly as much as softening the artesian well water, owing to the fact that but few parts of the plant could be reduced in size.

The chemicals required, according to Dr. Hutton's average figures, for softening the daily average quantity of water (2,400,000 gallons) and precipitating the suspended matter, soda being omitted in this case, are estimated as follows:

Lime, 6,600lbs. at ¼ cent	$16.50	
Alum, 600 lbs. at 2 cents	12.00	
		$ 28.50
Daily cost of operating the softening plant, and repairs		12.00
Pumping water from the springs into the tanks and conduit (maximum lift)		24.00
Daily operation of softening and delivering into City reservoir		$64.50

Therefore, the annual expense of softening the Poplar Springs water, to the extent of 2,400,000 gallons per day, and of delivering it into the city distribution reservoir, would be:

Interest on plant, at 4%	$21,572
Repairs and renewals of buildings and machinery.	1,500
Operation of softening and pumping, at $64.50 per day	23,543
	$46,615

To ascertain the net expense of softening this water, as against supplying it unsoftened, I append an estimate of cost for supplying it in its natural condition.

There would be a deduction of $51,990 for decrease of size of buildings, in the number of pumps and omission of softening plant, etc. The total cost of the work is estimated at $487,300.

The average daily cost of pumping, maintenance and delivery into the city distribution reservoir is $18, or $6,570 per annum.

Therefore, the annual expense of delivering the natural Poplar Springs water into the city distribution reservoir would be:

Interest on cost of plant, at 4%	$19,492
Repairs and renewals	1,000
Pumping, at $18 per day	6,570
	$27,062

From the above figures it is computed that the daily cost of ftening 2,400,000 gallons per day will be $53.57. Therefore, the st of softening 1,000 gallons of Poplar Springs water is 2.23 nts.

D.—Winnipeg River.

The only object in considering this somewhat distant source, in the reputed natural purity and softness of its water. tead of draining a limestone country, its water passes through ountry of azoic rocks, such as granite and gneiss, which do not tain minerals that by solution materially harden the water. It only necessary to tap the river and bring the water in its ural state into the City.

The nearest point at which it can be reached is above the uth of the Whitemouth River, a tributary from the south, and ut 54 miles from the City.

It has been suggested to go below this point and take the er from Lac du Bonnet, requiring a conduit perhaps 10 miles er and a corresponding loss of head by friction. The only fication for this suggestion would be the advantage of allowing uspended matter to settle in the lake by the reduced velocity e water in passing through it, and thus to get clearer water. turbidity of the water, existing during the latter part of summer, is, however, mainly caused by very fine and light cles of vegetable matter, and most of these would probably ain in suspension, unless the water came to an absolute rest, h it does not. The additional expense of going to Lac du net would therefore not be justified by getting at best but a y slight improvement in the clearness of the water during a rt time in the summer. A survey was therefore made from kenhead River to the nearest point where the river could be ched. Between the City and Brokenhead River the territory s sufficiently well known.

The character of the water cannot vary much between the outh of the English River and Lac du Bonnet, excepting that the hitemouth River might somewhat decrease the purity below its outh. Between the English and Whitemouth Rivers there are any rapids and falls, as well as bends, which vertically and terally so thoroughly mix the water that its quality can be nsidered the same anywhere in the current. The velocity being pid the water must retain fine matter in suspension.

The best point at which to take the water for the City is just above the mouth of the Whitemouth River. The Winnipeg River was examined as far up as three miles beyond this point.

The water was carefully scrutinized: It had a distinct brownish-yellowish color, was slightly turbid and full of fine suspended matter, which was evidently of vegetable origin. The water was frequently tasted. Its taste was not pleasant, and invariably slightly bitter, which is usual in waters containing much vegetable matter. No doubt for perhaps 9 or 10 months in the year this water is clear and very palatable.

Samples for analysis were taken near the point where an intake should be placed, and they well represent the average character of the Winnipeg River water at that time. The analyses (Appendix II) show a moderately good water, but a very high percentage of albuminoid ammonia, several times the quantity that is considered permissible in England for the drinking water of that country. But this high percentage, as already stated, is due to vegetable matter and is explained by the large areas of forests and muskegs situated on its drainage area. The very small percentage of free ammonia indicates almost no pollution by animal matter.

The plan (Plate III) and profile (Plate II) show the territory over which the water would have to be brought to the City. The elevation of the Winnipeg River where it could be tapped is 843 feet above sea level. The lowest elevation at which a pipe line could cross the high land between the Winnipeg and Brokenhead rivers is 940 feet, or 97 feet above the Winnipeg River. From this point the pipe would fall 163 feet to the City reservoir. The total length of pipe is about 285,000 feet, or 54 miles.

The pipe should be sufficiently large and durable to carry, as estimated before, 6,000,000 gallons per day, or 11.14 cubic feet per second. Due to the different gradients available, the diameter would be thirty inches from the Winnipeg River to Bird's Hill, and 28 inches thence to the City.

The loss of head in this conduit due to friction is assumed at 0.784 per 1,000, when carrying 6,000,000 gallons per day, and at 0.145 per 1,000 when carrying 2,400,000 gallons per day. If stave pipe is used, the friction may be slightly reduced.

There would be numerous summits on this pipe line where air-escape valves would have to be provided. The pipe is supposed to be laid in the ground so that the minimum earth covering would be 6¼ feet, or so that its centre would be 7½ feet below the surface, to prevent the water from freezing. The pipe would,

as in the other projects, discharge into the distribution reservoir in the City.

It is found that the necessary total lift to deliver the water of the river into the City's reservoir, is 146 feet for 6,000,000 gallons daily, and 106 feet for 2,400,000 gallons daily.

There is an ample quantity of water and depth of fall at the proposed intake to allow the pumping to be done by water-power. Yet, to build works for this purpose alone, and which would operate economically and without failure at both high and low water stages, would be a more expensive undertaking than to erect a steam pumping plant and use as fuel, wood which abounds in the neighborhood.

The cost of this plant is estimated as follows:

Land for pumping station and pipe line	$ 2,600
Preparing ground and roads	1,500
Intake works, well, etc	1,000
Building for pumps and boilers............	6,000
Chimney and foundations	1,000
Dwellings for men	2,000
Two horizontal triple expansion engines, with boilers	19,500
Pipe line to City, 34 miles	1,246,700
	1,280,300
Contingencies and engineering, 15 per cent..	192,100
	$1,472,400

The annual expense of delivering the Winnipeg River water to the extent of 2,400,000 gallons per day, into the City distribution reservoir would be:

Interest on cost of plant, at 4 per cent	$58,895
Repairs and renewals of buildings, pipe line and machinery	2,000
Pumping, at $25 per day......................	9,125
	$70,020

E.—Comparison.

It remains now to compare the several projects which have been examined, as to the quantity and quality of their water, and as to their relative economy.

Both the Assiniboine and Winnipeg Rivers are so large that even at seasons of greatest drought they can supply sufficient water for the City.

The Poplar Springs deliver sufficient water for about 40,000 persons. By sinking wells along the line of the conduit this quantity could be increased several times, and without question furnish sufficient water for 100,000 persons.

The artesian well supply can likewise furnish the required quantity. In order to obtain the same, it is only necessary to sink a sufficient number of wells in the western part of the City and extend them in a northerly direction.

If we compare the natural waters as to palatability, but irrespective of their softness, we may place them in the following order:

1. Poplar Springs.
2. Artesian Wells.
3. Winnipeg River.
4. Assiniboine River.

If we compare them as to softness, we must give them the following order:

1. Winnipeg River.
2. Poplar Springs.
3. Assiniboine River.
4. Artesian Wells.

Considering both the palatability and softness of these waters, when in their natural condition, I should feel inclined to place them in the following order:

1. Poplar Springs.
2. Winnipeg River.
3. Artesian Wells.
4. Assiniboine River.

If the hard waters are softened by a chemical process, and the Assiniboine River water is also filtered, I should consider the order of preference, as regards palatability and healthfulness of all four projects, as follows:

1. Poplar Springs.
2. Artesian wells.
3. Assiniboine River.
4. Winnipeg River.

The cost of softening 1,000 gallons of water in the several projects is as follows:

1. Assiniboine River..............2.22 cents.
2. Poplar Springs...............2.23 cents.
3. Artesian wells...............2.57 cents.

These differences of cost are so slight as to have hardly any weight in deciding upon the preference.

The cost of softening any of the Winnipeg waters, as here determined, is not so great, in my opinion, as to prevent its adoption, although it much exceeds the usual cost in England. If a family of five persons use 300 gallons of water per day the cost of softening their supply would be less than one cent per day. According to Dr. Hutton, the softening process would reduce the

carbonate of lime from 28 to 17 grains per gallon, a reduction of 11 grains. If we assume approximately that each grain of carbonate of lime per gallon increases the amount of soap necessary for 100 gallons by 2 ounces, then, if sufficient soap is ordinarily added to make the water soft, the softening process proposed for the City would save 1⅜ pounds of soap per 100 gallons of water used for washing purposes.

Comparing the projects as to cost, I shall state them, first, in the order of the necessary capital which must be expended at the outset, to deliver the water into the city reservoir:

NATURAL WATERS:

1. Artesian Wells	$ 107,400
2. Assiniboine River, filtered, ($119,440)	159,570
3. Poplar Springs	487,300
4. Winnipeg River	1,472,400

SOFTENED WATERS:

1. Artesian Wells	$161,870
2. Assiniboine River, filtered, ($123,000)	163,130
3. Poplar Springs	539,290

The figures given in parenthesis cover the cost of using filters that have settling compartments attached to them, thus obviating the use of large settling basins.

The Artesian well project, it will be seen, requires the least outlay, both when the water is softened, and when it is delivered in its natural state, excepting in the case where settling compartments are substituted for large settling basins in the Assiniboine River soft water project.

Secondly, these projects are given in the order of annual expense, including both interest on outlay and cost of operation.

NATURAL WATERS:

1. Artesian Wells	$ 9,676
2. Assiniboine River, ($15,968)	19,133
3. Poplar Springs	27,062
4. Winnipeg River	70,020

SOFTENED WATERS.

1. Artesian wells	$32,175
2. Assiniboine River ($34,195)	38,600
3. Poplar Springs	46,615

This comparison indicates that the artesian well supply is the least expensive, whether natural or softened water is supplied.

Next in order is the Assiniboine River supply. Using small settling compartments attached to the filters, the annual cost is reduced several thousand dollars. Owing to the somewhat experimental character in the use of such compartments, I prefer, however, at the present time to use the larger figure for comparison.

The greater cost of the Assiniboine River project is accompanied also with the disadvantage, that in its natural state the water is objectionable at certain seasons of the year, and that the future may see it more or less polluted. While filtration should remove this objection almost entirely, the latent danger will, nevertheless, still exist, and conscientious care and attention must be exercised to overcome it. No such danger exists in the artesian water.

It therefore appears that the artesian supply is not only cheaper, but also safer to use, than that obtained from the Assiniboine River.

In view of the advantages of soft over hard water, as stated in the introduction, the small expense per family would surely not be resisted, and I shall assume that you will prefer the supply of softened water.

III.

DISTRIBUTION SYSTEM.

After the water, soft and clear at all times, is delivered into the city reservoir, it is then necessary to distribute it in such a manner as to furnish the citizens with the quantity they need and also with a fire pressure.

It has already been said that for reasons of economy fire pressure should be furnished only when required. At other times the pressure should be moderate and reduced to a minimum during the latter half of the night. (Appendix IV A.)

The quantity of water consumed is greatest during the day and least during the night. The pipe and pumping system must therefore be proportioned to supply these varying quantities. Thus, it is assumed, that the maximum consumption is one and three-quarter times the average, or, for a mean supply of 2,400,000 gallons per day, it is taken at the rate of 4,200,000 gallons per day.

A distribution reservoir is therefore required to receive the water from the softening plant at a uniform rate, to store it and to enable the pumps to draw the quantity that may be required at any moment. (Introductory.)

The capacity of such a compensating reservoir is assumed at 1,000,000 gallons. While it is usual to make this capacity greater, so as to allow of a temporary stoppage of the delivery works for repairs, it is thought that the greater expense is hardly warranted in your case, owing to the proposed method of collecting and softening the water.

A tank reservoir is sometimes used in order to allow the pumping to be suspended during the night, when the draft is least. But such a suspension is not advisable in your city, unless the tank were placed sufficiently high to furnish fire pressure. Such a height is impracticable. Pumping must be continuous and the sole purpose of the reservoir is to compensate for the irregular draft.

A stand pipe is sometimes used to equalize the varying pressures, and to relieve the pumps of sudden strains and shocks. Modern pumping machinery, however, does not necessarily require his safeguard, as protection can be provided in other ways. Moreover a stand pipe would not be advisable in your climate for other asons.

The distribution reservoir should be built underground, and ered with masonry arches resting on piers. Its dimensions e been assumed at 106 feet square and the depth of water at feet.

The pumping station, at which the water is pumped from the servoir into the mains, should be the same as that at which it is mped from the wells to the basin of the softening plant. The onomy of operating a combined station is apparent. It should located beyond the Fair grounds and near McPhillips street.

The pumps have been estimated in duplicate and are to be of e best class, with triple expansion, so as to economize as much possible in fuel.

The pipe system starts with a twenty inch main, and conducts e water to the inhabited parts of the city.

Colonel Ruttan has suggested a pipe distribution system for is purpose, which I have examined and can fully approve, as eing well adapted to give both the quantity and pressure required. can also fully endorse his advice to have no mains smaller than ix inches in diameter, except in connecting two pipes from one

block to another, for which purpose a four inch pipe can be used, if no fire hydrant is connected with it. No four-inch pipes, however, have been included in the estimate of cost.

Fire hydrants in your climate should be of the post pattern, so that they can be readily seen when snow covers the ground. They should, if practicable, have a drip connection with a sewer or with a small pit provided for the purpose and filled with coarse gravel.

The length of pipes necessary for a population of 40,000 persons, I have estimated at 65 miles, while for a population of 100,000 persons this length might have to be increased only 40 per cent. As the buildings are now somewhat scattered and as they should all be supplied with water, excepting those at the outskirts, I did not think it well to estimate a smaller mileage.

The number of valves and hydrants are given at the minimum allowance that is usually considered permissible for the above pipe mileage.

It was stated in the Introduction that the consumption per inhabitant, particularly when the pressures will be increased, could not be kept as low as the rate assumed in this report, unless the water supplied to consumers is metered. I have therefore allowed for metering the entire supply.

It should be added here that the metres should be the property of the City. No control could otherwise be exercised over them, nor a guarantee offered that their registration was fairly accurate.

The service pipes leading from the mains to the buildings should be laid by the City. It is best that there should be a municipal control of all works located on public property and requiring the temporary removal of parts of pavements. But, as the service pipes are entirely in the interest and for the benefit of the respective consumers, it is proper that their cost should be borne by them and that these service pipes should be considered as a direct benefit to the property. Their cost is, therefore, not charged to municipal plant.

In establishing a waterworks plant provision should be made for a storehouse and repair shop, which are necessary adjuncts to the distribution system.

An estimate of cost of the entire distribution system, most of which will answer for a much larger population than 40,000 persons, is given below. It has been the intention to make this estimate liberal, so as to fully cover all contingent expenses. It

is of course unnecessary to lay a greater length of pipe or to set more hydrants than may be required at any given time.

Distribution Reservoir		$45,000
Pumping Station:		
Land	$ 2,000	
Preparing grounds	2,000	
Buildings, foundations, chimneys, etc	15,000	
Two horizontal, triple expansion, high duty pumps	76,000	
		95,000
Distribution Pipes:		
4,000 ft. 20 in. pipe, laid, at $4.60 per ft.	$18,400	
4,800 " 18 " " 3.80 "	18,240	
6,000 " 16 " " 3.20 "	19,200	
12,500 " 14 " " 2.60 "	32,500	
27,000 " 12 " " 2.10 "	56,700	
36,500 " 10 " " 1.70 "	62,050	
54,000 " 8 " " 1.30 "	70,200	
200,000 " 6 " " 0.90 "	180,000	
		457,290
Valves:		
3—20 inch valves, in position, at $230	$ 690	
3—18 " " " " 162	486	
4—16 " " " " 118	472	
13—14 " " " " 103	1,339	
18—12 " " " " 88	1,584	
27—10 " " " " 77	2,079	
50— 8 " " " " 65	3,250	
333— 6 " " " " 57	18,981	
		$28,881
Hydrants:		
350—8 inch hydrants, in position, at $130	$45,500	
220—6 " " " " 100	22,000	
		67,500
		$703,671
Meters:		
4950—⅝ inch meters, set in place, at $12.20	$60,390	
1230—¾ " " " 18.30	22,509	
350—1 " " " 24.40	8,540	
60—1½ " " " 42.00	2,520	
10—2 " " " 68.40	684	
		$94,643

Storehouse and machine repair shop	10,000
	$808,314
Contingencies and engineering, 10 per cent.	80,831
	$889,145

The annual cost of the distribution system, as above estimated, will therefore be as follows:

Interest on $889,145, at 4 per cent	$35,566
Pumping 2,400,000 gallons per day..............	13,140
Maintenance and repairs........................	5,000
	$53,706

IV.

UTILIZATION OF PARTS OF THE PRESENT SYSTEM.

The foregoing investigation has been made on the supposition that the franchise of the company now supplying the city with water soon expires, and that every obligation on the part of the City towards the company then ceases.

In such a case, the City would be free thereafter to adopt whatever source of supply, and to build whatever system of distribution it might deem best for its interests. The investigation for a new supply has therefore been made as though the present works were wholly private.

The resulting conclusions have indicated that another source than the present one would furnish better water and at a less expense. A question then arises: Cannot some parts of the present works be embodied in the better system? If so, there is no necessity for duplicating them, and the City should buy them from the company at a fair valuation.

As the pumping station of the proposed works would be in a different locality, only the pumping machinery and filters might perhaps be utilized.

The pumps operated by the company neither appear to be in first-class condition, nor are they designed to do as economical work as can be done by a higher type of machinery. At the time

when the franchise expires, it is a question whether the present pumps would be worth moving and re-erecting to perform so important a duty as would be expected of them. I therefore do not advise their purchase and have estimated for new machinery.

The filters are of a design which is not well adapted to the purpose of removing the crystaline precipitate caused by the softening of the well water. Their operation would be at least troublesome and expensive, and I can not recommend them as a part of the new system.

On the other hand, the piping can largely be utilized. I am informed that there are a few miles of old pipe, joined simply by contact and without lead. If these pipes cannot withstand the increased fire pressure, they have of course little or no value in the distribution system. The other pipes, namely, those having joints caulked with lead, and which constitute the major part of the system are reported to be in good condition. These pipes could therefore be embodied in the new works, wherever they allow sufficient circulation and pressure. Where they do not allow of this, the smallest pipes could be discarded and replaced by larger pipes to act as feeders.

The value of the pipes of a distribution system, when they have been in the ground for some years, is of course less than the value of new pipes, because their life is limited by being subject to gradual corrosion.

The value of the hydrants and valves is also dependent upon their actual condition, and those which are suitable might be embodied in the new system.

V.

METHODS OF PROPORTIONING THE PAYMENTS FOR THE SYSTEM.

The total annual cost of supplying the city with 2,400,000 gallons of water from Artesian wells, as estimated above, is as follows:

Softened and delivered into reservoir..........	$32,175
Distributed throughout city.....................	53,706
	$85,881

At this place it is proper to add an annual allowance for administration expenses and contingencies, which I place arbitrarily at $20,000. This gives a total annual expenditure of $105,881, to cover which a revenue must be provided.

This revenue is assumed to be met by the following payments:

1. The city at large pays for the water used for public purposes, such as fire extinguishing, street sprinkling, fountains, sewer flushing, etc.

By the use of meters or by estimate, it is practicable to determine this quantity with sufficient exactness. As the water does not need to be softened when used for these purposes, it might be considered fair to charge the city for the same at the cost of the natural well water, and it will be so charged in the following estimates.

2. The abutters to pipe lines pay an annual charge per running foot of pipe when laid in front of their property, whether it is improved and water is used or not.

This is a fair charge, because, after a water main adjoins a lot, the value of the lot is materially increased and the cause of such increase should be willingly paid for. If, for instance, the lot has 50 feet frontage, and the charge is 5 cents per foot, the annual assessment is $2.50. Assuming 5 per cent interest, the value of a 50 foot lot should have been increased $50 by the added water privilege. It can hardly be doubted that the real increase of value would be much greater. It is proper not to charge corner lots for the pipes laid on both frontages. A deduction should be made on the longest front for perhaps 50 feet back of the house line. This distance is assumed because it is not probable that a second house will be built upon such a lot within 50 feet. With this, or a similar allowance, and with the deduction for the street intersections, it is usually found that the assessable frontage is about two-thirds of the total mileage. As this was assumed at 65 miles, and as the property would be assessed on both sides of the pipe, at least 400,000 feet of frontage would be available for this charge.

3. Consumers to pay for the quantity of water they use.

There can be no question as to the propriety of paying in proportion to the benefits derived from a good water supply, and therefore in proportion to the amount of water used. The adoption of meters is rapidly increasing in America and Europe for this purpose of measuring water, as of measuring gas or other valuable commodities.

Assuming that you will adopt this modern and just mode of charging consumers, a rate per 1,000 gallons should be fixed; but as mentioned in the Intoductory, each consumer should be charged with a minimum price, irrespective of the quantity consumed, and pay the meter rates only for excessive quantities.

You will best know what you would prefer to state as a minimum rate, or how to adjust it. For purposes of estimate I shall assume that it is placed at 30 gallons per head per day. This quantity of water is nearly equal to that used per inhabitant in London, England. It should therefore be sufficiently liberal. On the other hand, if we compare it with the cousumption per inhabitant in the United States, it cannot be considered too liberal, and therefore a hardship upon the poorer classes. The average private consumption per head will be much greater, and, so far as the income is concerned, I think it can safely be placed at 60 gallons per head.

The works as estimated are to serve 40,000 persons. Therefore, the revenue should be based upon this number. This population, however, will not be served for a number of years after the works have been built. Therefore, an allowance should be made to cover the deficiency in the revenue. This purpose is served, I think, by proportioning the charge against consumers among 33,000 inhabitants, or, assuming 5 persons to the family, among 6,600 families or water takers. There is at present a smaller number within the territory to be furnished with water; there may be 8,000 families when the population taking water reaches 40,000 persons.

From what has been said regarding the method of paying for the works and for the water to be furnished, it is seen that the income is to be derived from three sources, the City at large, the abutters and the consumers. The City at large is charged for water, because it does not need to be softened, at a smaller rate than the consumers, on whose account the entire supply must be softened.

The following statement shows the probable income per annum:

1. City at large:

200,000 gallons per day at 12.5 cents per M.... $ 9,125

2. Abutters:

400,000 feet frontage at 5 cents per foot 20,000

3. Consumers (average):

33,000 persons at 60 gallons, or 1,980,000 gallons per day at 15 cents per M.............. 108,555

4. Lost, or not chargeable, 220,000 gallons..........

$137,680

Therefore, the annual charges would probably be $137,680.

It is thus seen that the charges apparently exceed the cost by over 30 per cent. In an enterprise like this one, having a few uncertain factors, it is a good business principle to rest it upon a safe basis. It is better to assume high rates, with a probability of reducing them in the future, than to resort to the unpopular necessity of increasing them

The rates can be practically reduced at any time by allowing a discount for prompt payment. The following statement shows the result when 20 per cent is allowed the abutters and consumers for this promptness, and supposing that every one were to avail himself of the privilege:

City at large	$ 9,125
Abutters	16,000
Consumers (average)	86,844
	$111,969

While this figure still exceeds the estimated cost, it is wise to keep it in excess, particularly at the beginning of the period, when the water takers are comparatively few and the outlay is great. In fact, the privilege of a discount should depend upon the actual conditions at any time, and the amount of the discount should be annually fixed by the City Council, in accordance with the necessities of the case.

It was stated to me that many of the poorer families are furnished with hard water by watermen at the rate of 25 cents per barrel, which is further said to last them about a week. Thus, they pay about $12 per annum. For the same money the city can furnish them with many times this quantity of clear and soft water throughout the year.

Let us suppose that a family does not use more than 30 gallons per head, or in all 150 gallons per day. At this rate they would consume 54,750 gallons per annum. They may choose to take advantage of a 20% discount for prompt payment or not,

provided the city can give this reduction. They may reside on a 25 foot, or on a 50 foot lot. The annual payments under these four conditions would be as follows:

50 foot lot,—		
	No discount	$10 71
	Discount	8 57
25 foot lot,—		
	No discount	9 46
	Discount	7 57

It is thus seen that the poorer classes would have but a moderate rate to pay, and get an ample supply of water therefor.

I have assumed a constant meter rate, whether the consumption is large or small. Sometimes large consumers are given a lower rate. This practice, however, is not just to the small consumers, as the cost of furnishing the water is practically the same per gallon in one case as in the other.

It should be added that the question of water supply must also be considered as to its influence on fire insurance rates. If a good fire pressure over the entire city can be furnished there will be a marked reduction in these rates, which will somewhat offset the water rates.

In conclusion, it should be said that the cost of water per 1,000 gallons decreases as the consumption increases. Therefore, the above-mentioned rates, which have been based on a consumption of 2,400,000 gallons per day, while they may not allow of being discounted at first, they may allow of even a greater discount than the one given above, when the consumption becomes greater. For this reason it was not thought necessary at present to estimate the actual cost of supplying water for a population of 100,000 persons.

It must also be stated that, as instructed, no allowance has been made for a sinking fund to pay off the debt which must be incurred for the works. As the machinery and other perishable parts thereof must in time be replaced, new appropriations will be therefore required.

There have been several assumptions made in this report merely for the purpose of illustrating certain features or conclusions. It is practicable for you to change those assumptions which do not pertain to strictly engineering questions if, in your

wisdom, others would better accommodate the citizens. I trust that I have stated such cases with sufficient clearness, so that, with whatever change you might make, you can still follow my argument to its legitimate conclusion.

Respectfully presented,

RUDOLPH HERING.

Attached to this report are;

APPENDIX I,—Canadian Pacific Well Test;

" II,—Chemical Analyses;

" III,—Dr. Hutton's Report on Softening Winnipeg Waters.

" IV,—Assumed Data and Prices.

PLATE I,—Profiles of Artesian Wells;

" II,—Profile of Conduit to Poplar Springs;

Profile of Conduit to Winnipeg River;

" III,—Plan showing Conduit Lines.

APPENDIX I.

Test of Canadian Pacific Railway Well.

WINNIPEG, 1st April, 1897.

From 18 o'clock, March 27th, until 18 o'clock, March 28th, no water was pumped, and at the end of this time the water in large well had risen to within a few inches of the ground level.

From 13 o'clock, March 29th, till 13 o'clock, March 30th, the large Dayton pump in the engine room was kept pumping continuously up to its greatest capacity, drawing water from the large well, and also from the old well between engine room and car shop.

The level of the water was measured each hour and is given below. At the end of the 24 hours it had not gotten quite down to the suction valve, as the combined flow of the two wells was more than the pump could overcome.

At 12:30, March 30th, the old well was shut off from the pump, and water pumped from the large well only, when the water rapidly sank in the large well, and was kept within a short distance above the suction valve for 24 hours, from 14 o'clock, March 30th, till 15 o'clock, March 31st.

Two tests were made to determine the slip of the pump, the strokes being counted for one hour while water was pumped into the tank and note taken of the volume of water pumped, the first test being made when the water was just covering the suction valve, and the second when there were about 12 feet of water over the suction valve. These gave 1.88 and 1.78 Imperial gallons respectively for each stroke of the pump, or an average of 1.83 Imperial gallons. The diameter of pump barrel is 7¼", stroke 14".

During the 24 hours from 13 o'clock, March 29th, to 13 o'clock, March 30th, the pump made 124,200 strokes, or an average of 86¼ strokes per minute. At 1.83 gallons per stroke this would come to 227,286 gallons per 24 hours, or 158 gallons per minute. During the 24 hours from 14 o'clock March 30th, to 14 o'clock March 31st, the pump made 82,740 strokes, or an average of 57.46 strokes per minute. At 1.83 gallons per stroke this would come to 151,414 gallons per 24 hours, or about 105 gallons per minute.

The average pressure of water in the discharge pipe of the pump was, during the first 24 hours' test, about 50 pounds per square inch, and during the second 24 hours, about 30 pounds per square inch. The pump could not be run so fast during the second 24 hours, as during the first, as the flow of water into the well was not sufficient to keep the pump supplied at that pace.

Attached are tables showing the level of the water in well and the speed of pump at various times during the test.

A. C. Frith,

Assistant Can. Pac. Ry. Co.

Distances of Water Below Platform in Well.

(Platform is 13.1 feet below the ground level.)

Date.	Time.	Water Level, Feet.	Date.	Time.	Water Level, Feet.
1897.			1897.		
March 29	13.15	2.25	March 30	13.35	11.92
"	14.15	4.25	"	14.10	11.68
"	15.15	6.45	"	15.15	11.55
"	16.15	7.84	"	16.15	11.90
"	17.15	8.68	"	17.15	11.10
"	18.15	8.76	"	21.00	8.51
"	19.15	8.60	"	22.00	8.66
"	20.15	8.90	"	23.00	9.69
"	21.15	8.79	"	24.00	10.47
"	22.15	9.83	March 31	1.00	10.76
"	23.15	9.60	"	2.00	10.84
March 30	24.15	8.89	"	3.00	10.86
"	1.15	9.60	"	4.00	11.02
"	2.15	10.00	"	5.00	11.04
"	3.15	10.66	"	6.00	10.61
"	4.15	11.00	"	7.00	10.50
"	5.15	11.16	"	8.00	11.05
"	6.15	11.30	"	9.00	11.60
"	7.15	10.68	"	10.00	11.70
"	8.15	9.62	"	11.00	11.72
"	9.55	9.00	"	11.45	11.50
"	10.45	8.80	"	13.00	11.46
"	11.45	9.06	"	13.50	11.05
"	12.50	9.45	"	14.55	9.85
"	13.15	11.30			

NOTE.—At 11.92 feet below platform the suction valve begins to draw air.

Number of Strokes made by Pump.

Date.	Time.	No. of Strokes.	Date.	Time.	No. of Strokes.
1897			1897		
March 29,	13.00	0	March 30,	14.00	0
"	13.49	2000	"	15.00	2240
"	14.37	4000	"	16.59	6000
"	15.00	5000	"	18.03	7700
"	16.09	8000	"	20.56	11840
"	16.55	10000	"	21.05	12000
"	17.40	12000	March 31,	6.55	29100
"	18.30	14000	"	7.26	30000
"	20.58	20000	"	7.55	31000
"	22.15	23100	"	8.28	32000
March 30,	7.19	48500	"	9.41	34300
"	7.33	49000	"	10.06	35000
"	8.00	50000	"	10.50	36200
"	8.52	52000	"	11.48	37800
"	9.35	54000	"	13.08	40000
"	10.25	55500	"	14.00	41370
"	11.37	58350	"	14.38	42000
"	13.00	62100	"	15.00	42600
"	13.40	62950			

Pump strokes not counted between 13:40 and 14 o'clock on March 30th.

APPENDIX II.

WATER ANALYSES.

All determinations expressed in parts per 100,000.

Assiniboine River.

Date of Collection.	ANALYST.	SOURCES.	PHYSICAL CHARACTER.	Total Solids.	Nitrogen estimated as free Ammonia.	Nitrogen estimated as Albumin'd Ammonia.	Nitrates and Nitrites.	Chlorine	Oxygen Consumed at 80° F. and Metallic Iron.	Deg. of hardness equivalent to parts of lime in 100,000 parts of water. Tem.	Per.	Total.
Aug. 30, 1892	Dr. Hutton..	Assiniboine River before filtering.	Slightly turbid, after clearing by subsidence has a slight brownish yellow color.	71.71	0.0074	0.0276	0.0092* 0.0074†	2.8	In 15 min. at 80° 0.165 In 4 hrs 0.477	9.8	33.	42.9
"		do. 2nd sample	" "	75.86	0.0074	0.029		2.8	do.	10.7	32.1	42.9
"	"	Assiniboine River after filtering drawn at laboratory.	....	63.43	0.0030	0.0242		2.23	At 80° In 15 min. 0.105 In 4 hrs 0.413			
Oct. 10-15, 1892	Dr. Drown..	Assiniboine River	Distinct clayey turbidity, considerable earthy and woody sediment. Odor (cold) faintly vegetable; odor (hot) distinctly vegetable and woody.	58.60		0.0206		2.45	Metallic Iron 0.1200			40.0

* Zink and copper couple. † Aluminium method.

Poplar Springs.

Date of Collection.	ANALYST.	SOURCES.	PHYSICAL CHARACTER	Total Solids.	Nitrogen estimated as free Ammonia.	Nitrogen estimated as Albumin'd Ammonia.	Nitrates and Nitrites.	Chlorine	Oxygen Consumed at 80° F. and Metallic Iron.	Deg. of hardness equivalent to parts of lime in 100,000 parts of water. Tem.	Per.	Total.
May 6, 1897	Dr. Hutton	Poplar Springs	Water in physical properties very similar to that drawn at Ross Ave. Sample, if anything clearer than the above. No sediment.	60.00	0.000	0.000		1.4		10.9	18.1	29.0
July 27, 1897	Dr. Kenrick	Poplar Spring	Clear and free from color. Had an alkaline reaction.	56.6	0.000	0.000		2.33		32.8	None	32.8

Winnipeg River.

Aug. 1, 1897.	Dr. Kenrick	Winnipeg River, above mouth of Whitemouth riv.	Color, yellow. Contained much suspended matter. Had an alkaline reaction.	31.1	0.0013	0.072		0.03				6.7
Aug. 1, 1897.	Dr. Hutton	do.	Color,—distinct brownish yellow with flocculent sediment. Odor, cold, none; warm, faint. Taste, at room temperature, flat and unpleasant.	11.2	0.000	0.050		0.35				11.6

Artesian Wells.

Aug. 4, 1892	Dr. Hutton	Exhibition gr'nds, flowing well at main entrance.	Bright, clear water, nearly colorless.	111.86	0.018	0.006		24.8		16.1	33.9	50.0
Aug. 4, 1892	Dr. Hutton	Exhibition gr'nds, (cattle sheds)	Bright, clear water, nearly colorless.	108.00	0.016	0.006		25.4		19.6	33.9	53.6

Aug. 16, 1892	Dr. Hutton..	Brookside (flowing well)	Cloudy, light brown color, deposits slight brown sediment on standing.	111.29	0.016	0.004		25.4				51.8
Aug. 16, 1892	Dr. Hutton	Logan Ave, west of C.P.R.	Cloudy, light brown color, slight deposit on standing	109.43	0.013	0.003	0.0142*	24.3		16.1	32.1	48.2
Aug. 24, 1892	Dr. Hutton..	Young St. (pump)	Bright, clear, nearly colorless, deposits slight sediment on standing.	115 00	0.019	0.004		27.1				53.6
Aug. 24, 1892	Dr. Hutton..	McDermot Ave. (flush tank).	Bright, clear, nearly colorless.	115.43	0.019	0.004		25.1				53.6
Oct 10-15, 1892	Dr. Drown .	Exhibition gr'nds.	Slight clayey turbidity, very slight sediment.	107.00		0.0034	0.0700 0.0001	23.42	Metallic Iron 0.0500			5[illegible].00
Sept., 1892	Dr. Girwood.	Brookside........	....	111.43	0.016	0.006		27.40				41.1
Sept., 1892	Dr. Girwood.	Logan Ave......	....	111.43	0.022	0.010		24.70				42.0
Aug. 21, 1895	Dr. Kenrick..	Leland Hotel....	Clear, colorless, odorless, and of excellent quality.	131.50	trace.	0.050	0.012	33.50	Oxygen consm'd in 15 min. 0.010 in 4 hrs. 0.012			
May, 6, 1897	Dr. Hutton..	Exhibition gr'nds.	Water clear when drawn, but on standing becomes cloudy and deposits a brownish sediment more or less crystaline under the microscope, and consisting chiefly of carbonate-of-iron. Slight odor and taste, probably due to iron piping.	113.40	0.016	0.003		26.40		16.3	32.7	49.0
May 6, 1897	Dr. Hutton..	Ross Ave.	Water bright and very clear almost as colorless as distilled water. No odor, pleasant to the taste and well aerated.	109.10	0.011	0.004		24.70		17.3	33.7	51.0

* Zink and copper couple.

APPENDIX III.

Abstract of a Report by Dr. Hutton on the Softening of Winnipeg Waters.

To render the water from the Artesian wells of Winnipeg satisfactory for domestic purposes, treatment with a mixture of milk of lime and a solution of carbonate of sodium would, in my opinion, be the best and most available process.

The quantities of materials required are as follows:

Lime, 300 to 350 lbs. per 100,000 gallons. Sodium carbonate, 40 to 50 lbs. per 100,000 gallons.

A very simple test, whereby it may be known when the proper quantity of lime has been added, is as follows:

A few drops of a 5 per cent solution of nitrate of silver added to the treated water causes the formation of a faint yellow precipitate. The color of this precipitate is white when insufficient lime has been used, but is brownish when too much lime has been added.

To make the treatment sucessful thorough agitation of the water after adding the softening materials is essential. The lime and the soda should be prepared separately, but may be added to the water at the same time. A small quantity of alum would hasten the settling, but is not absolutely necessary, because of the absence of organic matter.

The Poplar Spring water could be sufficiently softened by the addition of milk of lime alone, and would require about 250 to 300 lbs. of lime per 100,000 gallons. There is very little difference in total hardness between this spring and the present water supply.

The following observations on the rate of clarification with lime alone have been made:

Ross Ave. Well.—One-third of a 30-inch tube was comparatively clear in four minutes; the whole of the tube was comparatively clear in 25 minutes, and had completely settled in 15

hours. An addition of 0.025 parts of alum per 1000 parts of water caused settlement in $4\frac{1}{2}$ hours.

POPLAR SPRING.—One-third of the tube was comparatively clear in four minutes; the whole of the tube was comparatively clear in 40 minutes, and had completely settled in 18 hours. An addition of 0.025 parts of alum per 1000 parts of water caused settlement in five hours.

After softening, the water is bright and clear and tasteless at room temperature. When lime alone is used, the only change is the diminution of calcium and magnesium carbonates by about 60 per cent. Thirty pounds of lime added to 10,000 gallons of water would give a deposit of $61\frac{1}{4}$ lbs. of calcium carbonate.

When sodium carbonate is added as well as lime, it reacts on the sulphates of calcium and magnesium, changing them into the less soluble carbonates, and leaves in solution an equivalent quantity of sodium sulphate which is very soluble, harmless and non-soap-destroying.

The addition of the soda further decreases the hardness of the water from 10 to 20 per cent.

The rate of settling of the precipitates would be more rapid in shallow than in deep tanks, and much more rapid in tanks than in the glass tubes used for experiments.

(Signed) W. A. B. HUTTON.

Winnipeg, July 17th, 1897.

APPENDIX IV.

A.—Data assumed for purposes of comparison and for estimating cost of works.

Immediate provision for .... 40,000 persons.
Future provision for .... 100,000 persons.

Water pressures :

Fire pressure, 75 lbs. per square inch at hydrants in business centre, and 10 adjoining fire streams, each 35 cubic feet per minute.

Ordinary domestic pressure, 30-40 lbs. per square inch.

Minimum night pressure, 20-25 lbs. per square inch.

Consumption per head per day:	Imperial Gallons.	Cubic Feet. (Approx.)
Average rate,	60	9.6
Maximum rate,	105	16.8
Immediate total provision per day:		
Average rate,	2,400,000	384,000
Maximum rate,	4,200,000	672,000
Future total provision per day:		
Average rate,	6,000,000	960,000
Maximum rate,	10,500,000	1,680,000

APPENDIX IV.

B.—Prices assumed for labor, material, land, etc., in estimating cost of the works, in consultation with Col. H. N. Ruttan.

Excavation, Etc.:		
Earth, in trenches	$ 30	per cu. yd.
Earth, with boulders, part of conduit line	1 00	" "
Muskegs	60	" "
Rock, limestone in trench	2 50	" "
Rock, granite in trench	3 50	" "
Excavation for reservoirs, etc.	25	" "
Removal of surplus earth	25	" "
Sodding over Distribution Reservoir	15	per sq. yd.
Masonry, Etc.:		
Brick laid in Portland cement	20 00	per M.
Brick laid in Portland cement (700 brick per cubic yard)	14 00	per cu. yd.
Concrete, piers, arches, bottom and walls of reservoir	8 00 to 10 00	" "
Stone masonry	16 00 to 20 00	" "
Cement (400 lbs. per bbl., delivered in city)	4 00	per bbl.
Sand, in quantity	1 00	per cu. yd.

Brick (delivered anywhere in city)........	10 50	per M.
2 inch tile drains, laid..................	08	per foot.
6 inch drains, laid......................	25	"
Asphalt waterproofing for roof of distribution reservoir....................	40	per sq. yd.
Lumber and timber framed in structures ..	30 00	per M.
Lumber and timber, f.o.b. Winnipeg.......	18 00	"

Pipe, Castings, Etc.:

Cast-iron pipe, f.o.b. Winnipeg	$32 00	per ton.
Hauling pipe in city......................	30	"
Special castings..........................	50 00	"
Lead	4½	per lb.
Wrought iron, bars, straps, bolts, etc......	6	"

Valves and Hydrants: (Chapman Valve Co.)

36 inch stop valves, f.o.b. Winnipeg......	576 00	per valve
30 " " " "	437 00	"
18 " " " "	112 00	"
16 " " " "	70 00	"
14 " " " "	55 00	"
12 " " " "	42 00	"
10 " " " "	31 00	"
8 " " " "	21 00	"
6 " " " "	13 00	"
24 inch check valves, f.o.b Winnipeg	273 00	"
6 " " " "	22 00	"
8 " hydrants, " "	85 00	per hydr'nt
6 " " " "	62 00	"

Water Mains in City:

6 inch pipe laid, incl. valves, connections, &c	$ 90	per foot.
8 " " " " "	1 30	"
10 " " " " "	1 70	"
12 " " " " "	2 10	"
14 " " " " "	2 60	"
16 " " " " "	3 20	"
18 " " " " "	3 80	"
20 " " " " "	4 60	"

Fuel, &c.:

Cordwood, at Winnipeg River..............	$1 50	per cord.
Cordwood in City or at Poplar Springs....	5 00	"
Coal, bituminous (Penn.)	8 00	per ton.

CHEMICALS, in large quantities.

Soda	1 cent per lb.
Alum	2 cents "
Lime	$\frac{1}{4}$ cent "
Lime	15 cents per bushel of 60 to 70 lbs.

LAND, ETC. :

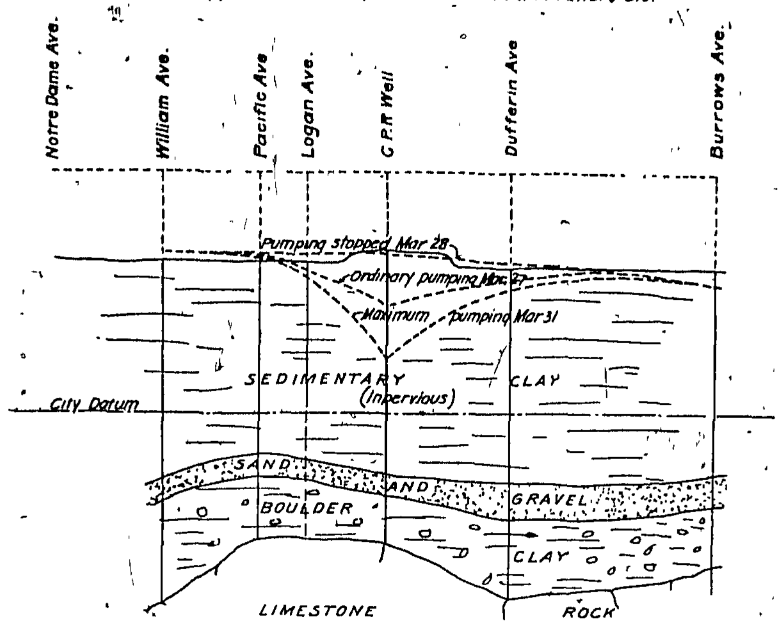
Near present pumping station	$1,000.00	per acre.
McPhillips street	300.00	"
Strip of land for artesian wells	250.00	"
Conduit line to Poplar Springs	20.00	"
Conduit line to Winnipeg River	5.00	"
At Poplar Springs	40.00	"
Pumping station site at Winnipeg River	1,000.00	

WAGES, SALARIES, ETC.

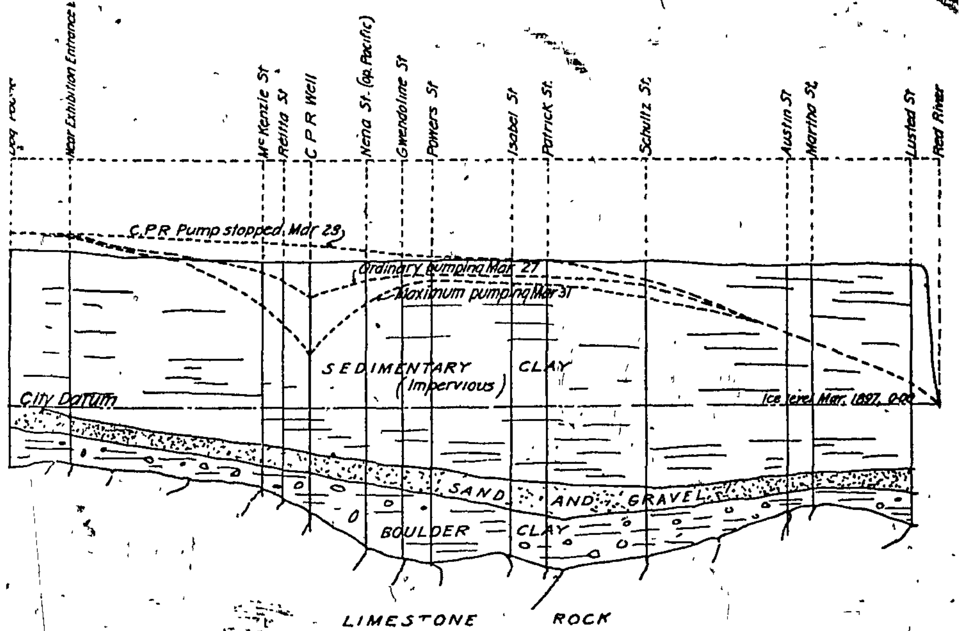
Common labor	15c. to 17½c.	per hour.
Skilled labor	25	"
Bricklayers	50	"
Carpenters (ordinary)	25	"
Masons	50	"

Salaried Men : Foremen	$100.00	per month.
Common laborers	40.00	"
Engineer at Pumping Station	120.00	"
Asst. " " "	75.00	"
Firemen " "	50.00	"

Approximate Section near Nena and Powers Sts.



Approximate Section on line of Can. Pac. Rwy.



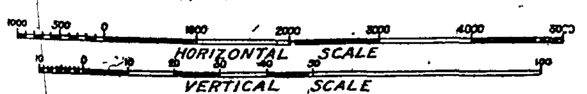


Plate I

To accompany Report of Rudolph Hering, 1897.

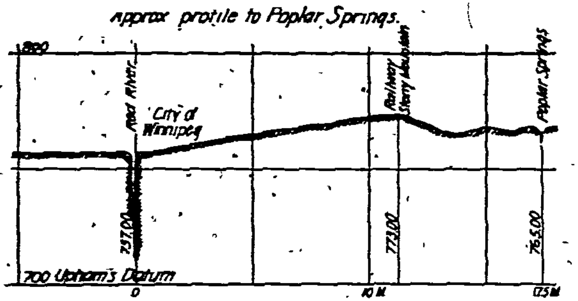
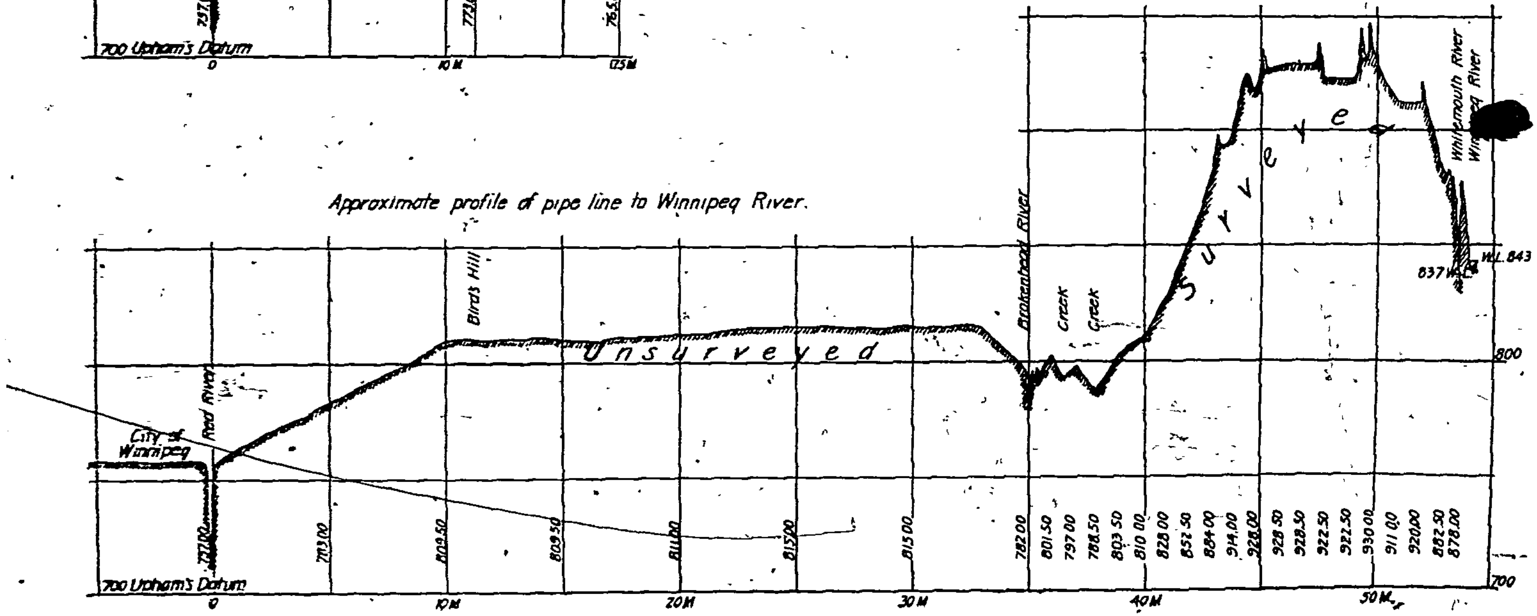


Plate II

To accompany Report of Rudolph Hering, 1897.



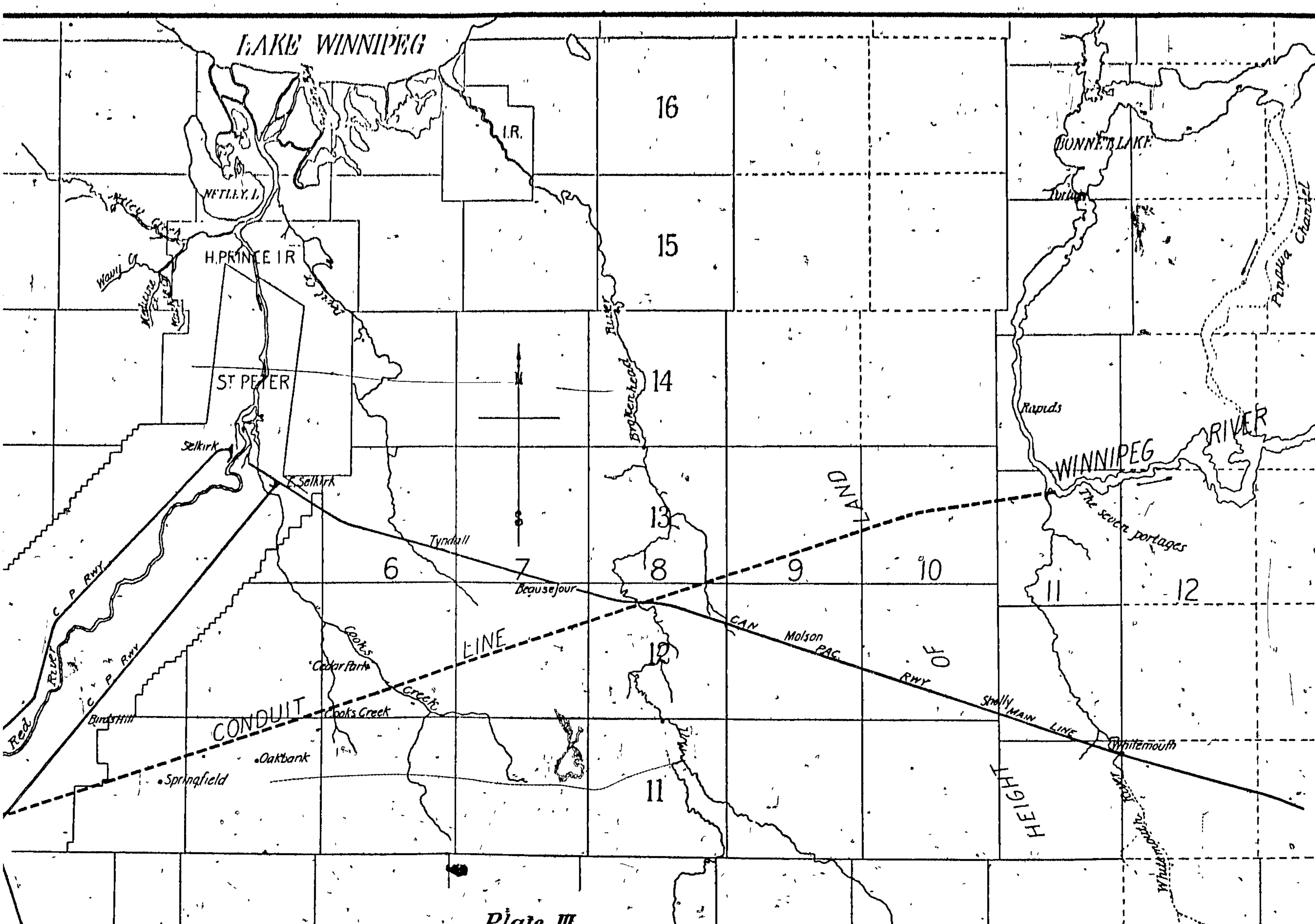


Plate III

[Pl]an showing Conduit lines to Poplar Springs and Winnipeg River,

to accompany Report of Rudolph Hering, 1897.

1 0 1 2 3 4 5 MI 10 15 MI
SCALE